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# EXPERIMENTAL ANALYSIS OF AERODYNAMIC DRAG REDUCTION OF A HATCHBACK MODEL CAR BY REAR SPOILER IN THE WIND TUNNEL

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***ABSTRACT***

***The main aim of this research is to optimize the various aerodynamic characteristics of the vehicle and to improve the fuel efficiency and vehicle performance by reducing the drag. The aerodynamic drag resistance is considered and minimized to reduce the fuel consumption. In this research, the drag resistance of the vehicle will be reduced by using the rear spoiler. The spoiler is designed and fabricated for achieving the best result in reducing the drag in a hatchback car model. The scaled model of the car is fabricated by using the aluminum material. The spoiler also designed using this aluminum material. The hatchback model car is analyzed without a spoiler and with a spoiler in the wind tunnel for the drag resistance. The comparison between the without and with spoiler arrangements on the scaled model car is also investigated.***

***KEYWORDS: Automobile Aerodynamic Characteristics, Rear Spoiler, Drag Reduction, Fuel Efficiency Improvement & Vehicle Performance Improvement***

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Original Article

## 1. INTRODUCTION

In the current scenario, the aerodynamic characteristics of the vehicles are highly recognized by the manufacturer. To achieve this, the various properties of the vehicle is considered while running. The improved aerodynamic property of the vehicle by using add-on devices makes a lot of improvement in the fuel efficiency. By reducing the drag of the vehicle the fuel efficiency will be improved. The better aerodynamics of the vehicle by add-on devices results in reducing drag, wind noise, minimizing noise emission. This will avoid the undesired lift forces and other causes of aerodynamic instability at high speeds. Another important thing is it will produce the downforce to improve the traction and thus cornering abilities.

## 2. SPOILERS

When the vehicle is in motion, the device which is used to spoil the turbulence effect of air is known as the spoiler. The front spoiler and rear spoiler is otherwise called as front wing and rear wing. These devices will be attached to the front part and rear part of the vehicle.

## 2.1. Design of the Car and Spoiler

### 2.1.1. Design and Dimensions of the Hatchback Car

The solid model of the car has been designed and fabricated in the ratio of 1:10 with respect to the given dimensions of the specifications using the aluminum material.

**Figure 1: Solid Model of the Hatchback Car**

**Figure 2: Pressure Port Tubes of the Scaled Model Hatchback Car**

**Table 1**

| Specifications | Dimensions (mm) |
|---|---|
| Overall Length (mm) | 3595 |
| Overall Width (mm) | 1650 |
| Overall Height (mm) | 1900 |
| Wheel Base (mm) | 2400 |
| Ground Clearance (mm) | 165 |
| Front Track (mm) | 1295 |
| Rear Track (mm) | 1290 |

Holes are drilled on the profile of the car to fix the tubes inside to measure the pressure.

Number of pressure port – 80, Port Diameter - 2 mm, Front side - 28 ports, Topside – 36 ports,

Rear side - 16 ports, Middle – 28 ports

### 2.1.2. Design and Dimensions of the Spoiler

A newly designed and fabricated spoiler is used in this research. It is manufactured by using the aluminum material. It is going to be analyzed with hatchback model car by fixing at the rear side.

The design and dimensions of the rear spoiler are as follows:

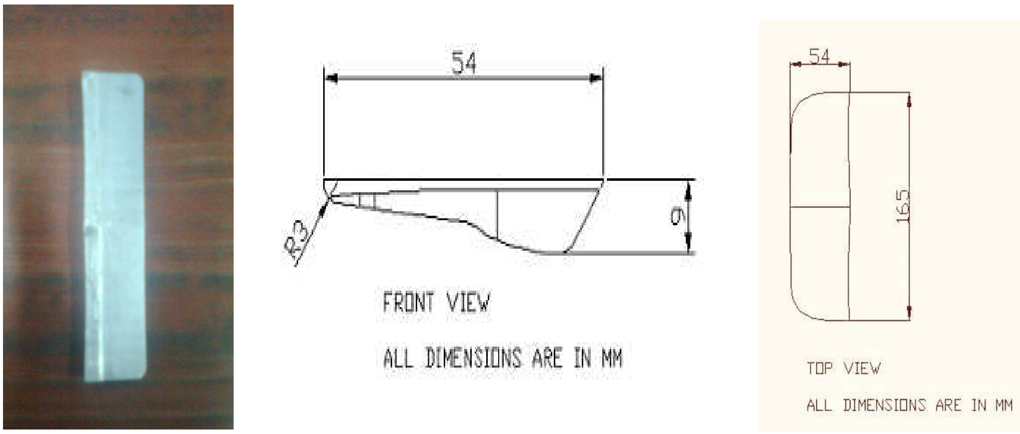


**Figure 3: Dimensions of Spoiler**

## 3. WIND TUNNEL TEST FACILITY FOR EXPERIMENT

The aerodynamic study of the car model of scale ratio 1:10 was conducted using subsonic suction type wind tunnel. The subsonic wind tunnel facility can be viewed as an experimental facility wherein the wind flow is simulated in a controlled manner to represent the flow characteristics in the nature and the aerodynamic forces and responses of the model are investigated in a scientific manner.

The subsonic wind tunnel main elements include

- The inlet section
- Test section
- Exit section

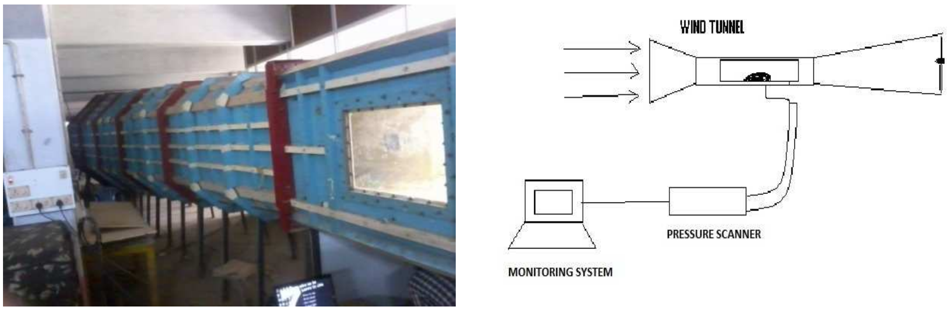


**Figure 4: Subsonic Wind Tunnel and Experimental Setup Arrangement**

### 3.1. Wind Tunnel Specifications

- It has a test section cross section of 3 ft. × 4 ft.
- It is a suction type wind tunnel.
- The maximum rpm attained by the drive is 1500.
- Horsepower is 170 HP.
- Output rating power 160 KW.

- Supply voltage is 415 V.
- Variable speed is 0.5-20 m/s.

## 4. EXPERIMENTAL TESTING OF A MODELED CAR WITHOUT SPOILER IN THE WIND TUNNEL

### 4.1. Experimental Testing of Scaled Model Car

The reduced scaled model car with sleeves and tubes is placed in the wind tunnel test section and the other ends of the tubes are connected with the ports available in the scanivalve. The scanivalve pressure scanner is connected to the computer to find the pressure value readings through the valve scan software. The pressure value measurement is taken with different velocities of air by adjusting the rpm of the fan drive motor.

**Figure 5: Hatchback Car Model inside the Wind Tunnel Test Section**

**Figure 6: Scani valve with Ports and Tubes**

### 4.2. Coefficient of Pressure ($C_P$) Distribution at the Mid Plane of the Car Without Spoiler of Different Velocities

**Table 2**

| Location | Port No. | 4 m/s | 8 m/s | 12 m/s | 16 m/s | 20 m/s |
|---|---|---|---|---|---|---|
| M1 | 1 | -0.26 | -0.14 | -0.12 | -0.11 | -0.10 |
| M2 | 2 | -0.45 | -0.23 | -0.19 | -0.17 | -0.16 |
| M3 | 3 | -1.44 | -1.32 | -1.36 | -1.26 | -1.16 |
| M4 | 4 | -1.36 | -0.93 | -0.92 | -0.90 | -0.87 |
| M5 | 5 | -1.02 | -0.78 | -0.79 | -0.75 | -0.72 |
| M6 | 6 | -0.82 | -0.64 | -0.64 | -0.64 | -0.61 |
| M7 | 7 | -0.98 | -0.86 | -0.92 | -0.95 | -0.93 |
| M8 | 8 | -0.87 | -0.88 | -0.93 | -0.94 | -0.91 |
| M9 | 9 | -0.99 | -0.97 | -1.03 | -1.03 | -1.00 |
| M10 | 10 | -1.28 | -1.02 | -1.16 | -1.60 | -1.53 |
| M11 | 11 | -1.91 | -1.76 | -1.87 | -1.88 | -1.82 |
| M12 | 12 | -1.78 | -1.59 | -1.70 | -1.70 | -1.64 |
| M13 | 13 | -1.44 | -1.38 | -1.43 | -1.42 | -1.37 |
| M14 | 14 | -1.54 | -1.34 | -1.43 | -1.44 | -1.39 |
| M15 | 15 | -1.40 | -1.31 | -1.39 | -1.39 | -1.34 |
| M16 | 16 | -2.37 | -1.33 | -1.32 | -1.37 | -1.30 |
| M17 | 17 | -1.57 | -1.30 | -1.32 | -1.36 | -1.28 |
| M18 | 18 | -1.41 | -1.19 | -1.21 | -1.24 | -1.17 |
| M19 | 19 | -1.45 | -1.16 | -1.20 | -1.23 | -1.15 |
| M20 | 20 | -1.34 | -1.16 | -1.20 | -1.22 | -1.15 |
| M21 | 21 | -1.56 | -1.35 | -1.40 | -1.44 | -1.36 |
| M22 | 22 | -1.43 | -1.22 | -1.25 | -1.29 | -1.22 |
| M23 | 23 | -1.19 | -1.12 | -1.16 | -1.19 | -1.12 |

**Table 2: Contd.,**

| | | | | | | |
|---|---|---|---|---|---|---|
| M24 | 24 | -1.20 | -1.11 | -1.16 | -1.19 | -1.12 |
| M25 | 25 | -1.12 | -1.08 | -1.14 | -1.18 | -1.12 |
| M26 | 26 | -1.34 | -1.13 | -1.17 | -1.20 | -1.13 |
| M27 | 27 | -1.36 | -1.14 | -1.17 | -1.21 | -1.14 |
| M28 | 28 | -1.14 | -1.11 | -1.17 | -1.23 | -1.17 |

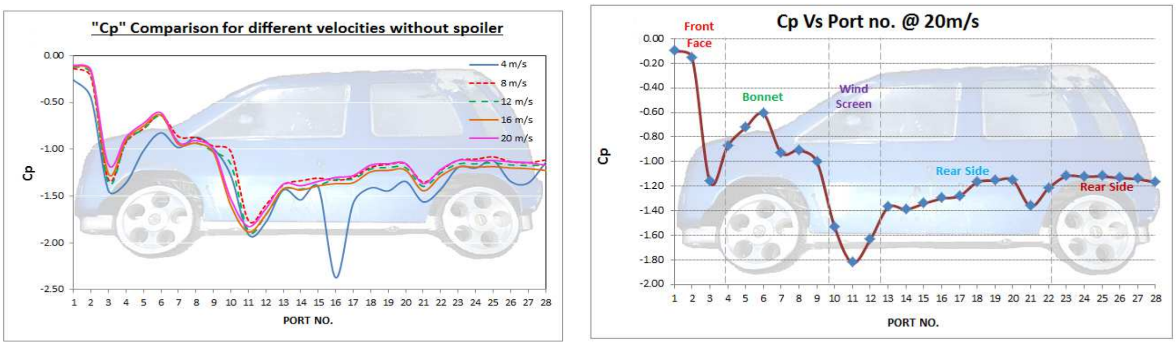


**Figure 7: Comparison Graph for different Velocities of Car Without Spoiler and Individual Graph of Pressure Distribution for 20 m/s**

### 4.3. Tabulation of Drag Force and Drag Coefficient with Velocity of a Car without Spoiler

**Table 3**

| S. No. | Velocity (m/s) | Drag force - "$F_d$"(N) | Drag Coefficient - "$C_d$" |
|---|---|---|---|
| 1. | 4 | 6.97 | 0.84 |
| 2. | 8 | 7.64 | 0.80 |
| 3. | 12 | 9.12 | 0.75 |
| 4. | 16 | 12.74 | 0.72 |
| 5. | 20 | 15.38 | 0.70 |

## 5. EXPERIMENTAL TESTING OF A MODELED CAR WITH SPOILER IN THE WIND TUNNEL

### 5.1. Experimental Testing of Scaled Model Car with Spoiler

**Figure 8: Hatchback Car Model with Spoiler Attached at the Rear Side and Kept Inside the Wind Tunnel test Section With the Arrangements of Scani Valve Ports and Tubes**

### 5.2. Coefficient of Pressure ($C_P$) Distribution at the Mid Plane

**of the Car with Spoiler of Different Velocities**

**Table 4**

| Location | Port No. | 4 m/s | 8 m/s | 12 m/s | 16 m/s | 20 m/s |
|---|---|---|---|---|---|---|
| M1 | 1 | -0.26 | -0.13 | -0.11 | -0.10 | -0.10 |
| M2 | 2 | -0.46 | -0.22 | -0.18 | -0.17 | -0.15 |
| M3 | 3 | -1.23 | -1.16 | -1.25 | -1.29 | -1.21 |
| M4 | 4 | -1.23 | -0.94 | -0.91 | -0.93 | -0.86 |
| M5 | 5 | -1.01 | -0.79 | -0.80 | -0.83 | -0.76 |
| M6 | 6 | -0.83 | -0.55 | -0.55 | -0.58 | -0.56 |
| M7 | 7 | -0.85 | -0.72 | -0.77 | -0.83 | -0.83 |
| M8 | 8 | -0.75 | -0.73 | -0.80 | -0.86 | -0.85 |
| M9 | 9 | -0.84 | -0.84 | -0.90 | -0.98 | -0.95 |
| M10 | 10 | -1.04 | -1.17 | -1.13 | -1.06 | -1.12 |
| M11 | 11 | -1.68 | -1.55 | -1.66 | -1.77 | -1.72 |
| M12 | 12 | -1.60 | -1.41 | -1.51 | -1.60 | -1.54 |
| M13 | 13 | -1.33 | -1.27 | -1.30 | -1.36 | -1.30 |
| M14 | 14 | -1.34 | -1.18 | -1.27 | -1.36 | -1.32 |
| M15 | 15 | -1.22 | -1.15 | -1.23 | -1.31 | -1.27 |
| M16 | 16 | -1.26 | -1.08 | -1.16 | -1.15 | -1.14 |
| M17 | 17 | -1.38 | -1.20 | -1.24 | -1.27 | -1.19 |
| M18 | 18 | -1.13 | -1.08 | -1.13 | -1.16 | -1.08 |
| M19 | 19 | -1.39 | -1.12 | -1.14 | -1.15 | -1.07 |
| M20 | 20 | -1.09 | -1.06 | -1.11 | -1.14 | -1.07 |
| M21 | 21 | -1.33 | -1.24 | -1.32 | -1.36 | -1.28 |
| M22 | 22 | -1.24 | -1.14 | -1.19 | -1.23 | -1.15 |
| M23 | 23 | -1.15 | -1.07 | -1.09 | -1.11 | -1.04 |
| M24 | 24 | -1.12 | -1.03 | -1.07 | -1.10 | -1.03 |
| M25 | 25 | -1.00 | -0.99 | -1.06 | -1.10 | -1.04 |
| M26 | 26 | -1.32 | -1.10 | -1.11 | -1.15 | -1.08 |
| M27 | 27 | -1.44 | -1.12 | -1.13 | -1.15 | -1.08 |
| M28 | 28 | -1.27 | -1.10 | -1.13 | -1.16 | -1.09 |

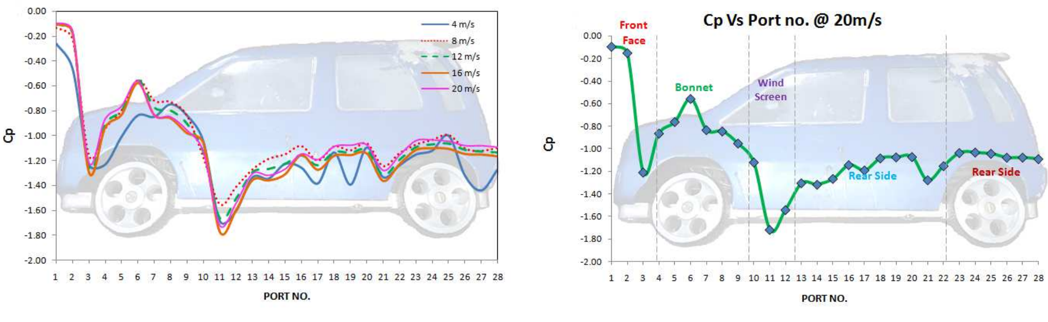


**Figure 9: Comparison Graph for Different Velocities of Car with Spoiler and Individual Graph of Pressure Distribution for 20 m/s**

From the graphical representation of the pressure distribution on the passenger car, it can be studied that the car without spoiler has higher pressure variation at different velocities. The car with spoiler has lower pressure variation curves comparing with the car without spoiler. From the experimental investigation, near the bumper of the car there is an area of very high pressure region said to be stagnation point. The velocity of the fluid reaches zero in this area. There is a region of low fluid velocity behind the boot of the car this is the wake of the vehicle. At very high velocities the coefficient of pressure of the car with spoiler will be very effective.

### 5.3. Tabulation of Drag Force and Drag Coefficient

**with Velocity of a Car with Spoiler**

**Table 5**

| S. No. | Velocity (m/s) | Drag force - "$F_d$"(N) | Drag Coefficient - "$C_d$" |
|---|---|---|---|
| 1. | 4 | 4.33 | 0.69 |
| 2. | 8 | 5.51 | 0.60 |
| 3. | 12 | 7.27 | 0.55 |
| 4. | 16 | 10.04 | 0.49 |
| 5. | 20 | 14.20 | 0.41 |

## 6. COMPARISON OF DRAG FORCE OF WITHOUT SPOILER AND WITH SPOILER OF A CAR MODEL USING GRAPHICAL REPRESENTATION.

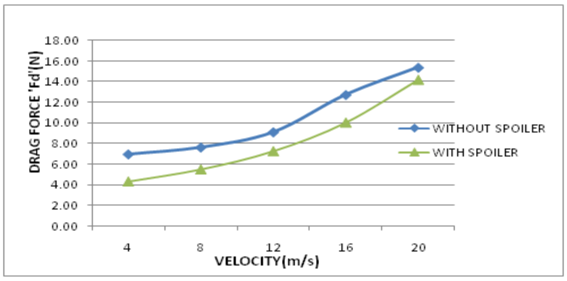


**Figure 10: Comparison Graph of Drag Force of without Spoiler and with Spoiler**

From the graph, it can be shown that the car without spoiler has higher drag force compared with the car with the spoiler. This is due to the turbulence or wake effect of the car on the rear side. The car with the spoiler has lesser drag force. This is because of the spoiler which accomplishes by increasing the turbulence flowing over the shape ‘spoiling’ the laminar flow and providing a cushion for the laminar boundary layer. The car with rear spoiler will be very effective in reducing the drag force.

## 7. COMPARISON OF DRAG COEFFICIENT OF WITHOUT SPOILER AND WITH SPOILER OF A CAR MODEL USING GRAPHICAL REPRESENTATION

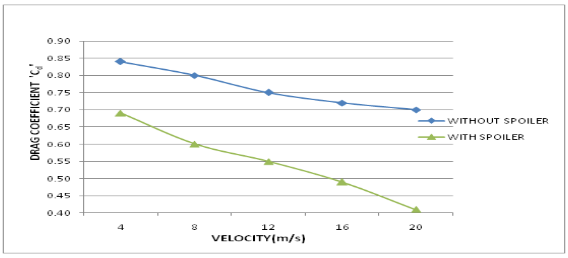


**Figure 11: Comparison Graph of Drag Coefficient of without Spoiler and with Spoiler**

The graphical representation indicates that the drag coefficient of the car without spoiler is high. This is due to the turbulent zone behind the car without spoiler is more. The reason is the air after passing over the rear windshield travels directly to the ground. That air has a higher speed and comes in to collision behind the car with the air from below the car which has a lower speed. However from the graphs it can be shown that the drag coefficient of the car with spoiler is less

compared with the car without spoiler. This is due to the maximum pressure amount is on the top surface of the rear spoiler, and the result of that is generating a downforce. By the addition of rear spoiler on the car, the velocity streamlines are narrowing which results in less turbulence behind the car. The low drag coefficient implies that the streamline shape of the vehicles body is such as to enable it to move easily through the surrounding viscous air with minimum of resistance.

## 8. CONCLUSIONS

The consideration of the various aerodynamic characteristics of the vehicle to improve the vehicle performance and to reduce the drag resistance is quite possibly achieved. The reduced scale model of the hatchback car in the ratio of 1:10 is tested in the wind tunnel test without spoiler. And then the car with spoiler is also tested. From the graphical results it can be seen that in the pressure readings of the car with spoiler is lesser than the car without spoiler. The aerodynamic drag force and the drag coefficient is slightly reduced up to 20% to 30% by using the rear spoiler.

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